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PREY CAPTURE AND STINGING BEHAVIOR IN THE EMPEROR SCORPION, *PANDINUS IMPERATOR* (KOCH) (SCORPIONES, SCORPIONIDAE)

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ABSTRACT

Prey capture behavior in the emperor scorpion, *Pandinus imperator,* is described and an ontogenetic change in prey capture behavior reported. Young scorpions up to 6 cm in length stung nearly all prey items. At 10 cm in length these scorpions stung only large, violently struggling prey items. Adult scorpions never used the sting, dispatching prey with the pedipalps and apparently refusing prey too large to subdue with the pedipalps alone. Prey capture behavior in *P. imperator* is compared with other species and the possible survival values of sting use is discussed.

INTRODUCTION

The stinging behavior of scorpions is well known as a means of prey capture and defense. However, the willingness to use the sting appears to vary greatly with the species. The emperor scorpion, *Pandinus imperator* (Koch), is one of the largest living scorpions, reaching a total length of over 17 cm. Inhabiting tropical west Africa, it is a forest dwelling species (Cloudsley-Thompson 1958).

During feeding captive adult emperor scorpions were never observed to sting their prey (usually common house crickets, *Acheta domesticus* Linnaeus). In the fall of 1980 one of the scorpions gave birth to six young. Interesting was the fact that the mother scorpion had been individually caged, without contact with other scorpions, for at least two years prior to giving birth. This suggests that sperm retention or some type of developmental interruption can occur in this species. The mother died of unknown causes soon after giving birth and subsequently only two young survived. The young scorpions, in direct contrast to the adults of their species, stung their prey at every opportunity, often stinging crickets 2 or 3 times. As they grew larger this behavior waned, until at some 6-8 cm in length they no longer used their sting on crickets.

Having observed this declining use of the sting with growth, it was decided to explore under what, if any, conditions the sting would be employed in prey subdual. Various sizes of prey items were offered to the scorpions, to test the idea that prey over a certain size threshold would stimulate sting use.

METHODS

Seven individuals of *P. imperator* were maintained in 32 cm X 7 cm terraria with 1-2 cm sanitary processed ground clay (Hartz® cat litter) as substrate. A bottle cap containing water was the only cage furnishing. Five individuals were adults at least four years of age and ranging form 14 cm to 17 cm in length (measured from tip of chelicerae to tip of telson). Adults were housed individually. Two individuals were 2.5 years of age and 10 cm in length. These were sibling littermates and were housed together. Temperatures during the three month study period ranged from 16-26° C, varying with outside temperature. No artificial sources of heat or light were provided. Various sizes of the common house cricket, *A. domesticus,* and the common house mouse, *Mus musculus* Linnaeus, were offered to the scorpions as prey. Time between feedings was generally one week.

RESULTS

Table 1 shows the results of 35 feeding trials with mice. In four trials the sting was used, in one trial there was an unsuccessful attempt to sting, in 24 trials the prey was subdued without using the sting, and in six trials the scorpion refused to feed. All four instances of sting use were by the smaller, younger scorpions. In no instance did the large adult scorpions attempt to sting. Moreover, none of these scorpions stung crickets of any size, generally devouring them alive. Mice which were not stung were killed by the crushing action of the pedipalps, except in two instances where very small mice were devoured alive.

A typical encounter was as follows (terminology after Bub and Bowerman 1979). Upon opening the terraria the scorpion would either back into a corner with the legs and pedipalps retracted, making itself as small as possible, or would assume an alert stance in which the scorpion is supported above the substrate by the legs, the pedipalps are extended anteriorly, and the metasoma is curled over the back. Initially the pedipalps would often be raised 1-2 cm above the substrate. Upon introducing the mouse and closing the terraria the alert stance would usually be modified by placing the movable fingers of the pedipalpal chelae and the pectines in contact with the substrate. If the scorpion had cowered in a corner an alert stance would be assumed a minute or two after the terraria was closed with the mouse inside.

Next the scorpion orients, directing its anterior aspect towards the prey. Orientation occurred only when the prey was active, the scorpion seemingly being unable to orient if the mouse remained motionless. The scorpion would next approach to within 5-10 cm of the prey. During orientation and approach the pedipalpal chelae and the pectines are raised off the substrate, only to be lowered again when the scorpion halts its progress.

Finally there occurs the attack and grasp attempt, in which the scorpion rushes at the prey with the pedipalps extended and held widely apart, so as to form a sort of corral. Contact is often made seemingly by accident, the scorpion apparently bearing down on the general vicinity of the prey with the extended pedipalps sweeping a wide enough area to make contact likely. The attack culminates in the grasp attempt, in which the scorpion attempts to obtain a firm

Table 1.—Feeding response of *P. imperator* to *Mus musculus*. Scorpion lengths measured from tip of chelicera to tip of telson. Mice: Group A-3.0 cm (snout to vent length), hairless, eyes closed; B-3.8 cm, furred, eyes closed; C-4.0 cm, furred, eyes closed; D-5.0 cm, furred, eyes open; E-5.1 cm, furred, eyes open.

Scorpion	Mouse group	Sting use	Remarks
1-10 cm	A	no	devoured alive
	B	no	killed by pedipalps
	C	yes	stung once midbody
	D	yes	stung once midbody
	E	—	refused
2-10 cm	A	no	devoured alive
	B	no	killed by pedipalps
	C	unsuccessful attempt	attempted sting in head but did not penetrate, subsequently killed by pedipalps
	D	yes	stung once midbody
	E	yes	stung once at shoulders
3-14 cm	A	no	killed by pedipalps
	B	no	killed by pedipalps
	C	no	killed by pedipalps
	D	—	refused
	E	—	refused
4-14 cm	A	no	killed by pedipalps
	B	no	killed by pedipalps
	C	no	killed by pedipalps
	D	no	killed by pedipalps
	E	no	killed by pedipalps
5-15 cm	A	no	killed by pedipalps
	B	no	killed by pedipalps
	C	no	killed by pedipalps
	D	—	refused
	E	—	refused
6-15 cm	A	no	killed by pedipalps
	B	no	killed by pedipalps
	C	no	killed by pedipalps
	D	no	killed by pedipalps
	E	no	killed by pedipalps
7-17 cm	A	no	killed by pedipalps
	B	no	killed by pedipalps
	C	no	killed by pedipalps
	D	no	killed by pedipalps
	E	—	refused

hold on the prey with at least one pedipalp. If the prey at any time runs away or otherwise eludes the scorpion or manages to free itself from a successful grasp, the scorpion performs the sequence of orientation, attack, and grasp attempt all over again.

Once the prey is successfully grasped by one pedipalp the scorpion immediately obtains a hold with the other pedipalp as well. At this point the prey is held well away from the mouthparts and often slightly elevated, so as to prevent purchase on the substrate which might facilitate its struggling. Biting and clawing by the prey is also thus restricted to attacks on the pedipalps, the cuticle of which is sufficiently durable to withstand any damage. Should the prey struggle violently it may be subdued by one or both of two methods.

In the first method, the scorpion may use the pedipalps as killing or maiming weapons. Often this entails obtaining new and more effective holds on the prey than those found with the initial grasp. Consequently one pedipalp may release its grip and regrasp elsewhere. Usually the scorpion will grasp the prey at either end, thereby obtaining a head grip with one pedipalp that is frequently lethal when force is applied. Violently struggling prey is often repeatedly passed from pedipalp to pedipalp in an attempt to find an effective grip. Scorpions will occasionally intentionally release and retreat from violently struggling prey, only to attack again. Larger prey items often escaped during regrasping attempts, necessitating reorientation and a new attack by the scorpion.

In the second method, the sting may be used to subdue prey after a successful grasp attempt. This only occurred if the prey struggled violently. In the four instances of stinging observed, struggling ceased almost immediately upon aculeus penetration, with cessation of breathing and apparent death from 90 to 180 seconds later. In the four instances observed the prey was stung only once. Rather than a quick jab, the metasoma was leisurely arched over the back and the telson used to probe the prey for a soft spot if one was not immediately encountered. The aculeus was inserted for 5 to 15 seconds, presumably injecting venom. The sting was always preceded by attempts to subdue the prey with the pedipalps. A firm grip was maintained by the pedipalps during stinging.

Once the prey is subdued ingestion begins. The pedipalps bring the prey in contact with the chelicera, which tear off pieces of flesh and convey them to the oral cavity. *P. imperator* may feed for two days on a carcass before leaving it, apparently disdaining stale food. The prey is often alive when ingestion commences.

DISCUSSION

Notes on sting employment in prey subdual are very scarce in the literature. McDaniel (1968) divided California scorpions into two groups on the basis of their habits and morphology. Errant types are characterized by long legs, a slender body, a large thick cauda with a large telson, and chelae with a long slender tarsus and tibia. These are described as actively pursuing prey and having rapid stinging reflexes. *Paruroctonus sylvestrii* (Borelli) is of this type. The second type is the obligate burrower, with a stouter body, shorter and more slender cauda, and broad chelae with short, sturdy tarsus and tibia. These are described as waiting for prey to come to them rather than pursuing it and relying on the pincers rather than the sting. Here *Anuroctonus phaiodactylus* (Wood) is an example. Williams (1966) also discusses burrowing activities in the scorpion *A. phaiodactylus* and again notes that the pedipalps are distinctively thick, heavy, and powerful; they are the primary means of catching and immobilizing prey.

Stahnke (1966) notes that the sting is used as an offensive weapon "when the prey is obstreperous and will not quietly submit to being devoured alive" and that "scorpions with powerful chelae depend largely upon their pinching and crushing ability for both offensive and defensive action." Fabre (1923), in working with *Buthus occitanus* (Amoreux), noted that the sting was frequently employed to subdue struggling insects. Southcott (1955) found that *Urodacus manicatus* (Thorell) invariably stings its prey as soon as it is captured. By contrast, Schultze

(1927) recorded that he had never seen the large Philippine forest scorpion, *Heterometrus longimanus* (Herbst), sting its prey. Schultze believed that "the poisonous stinger us used only as a defensive weapon against its enemies." In Schultze's experiments the prey (cockroaches) was held clear of the ground and eaten while still struggling. Vachon (1953) writes that in capturing its prey the scorpion "moves slowly forward, supported on its hind legs, with claws open and extended and tail raised and pointing forwards. Often the scorpion will then hesitate, and the final act of capture seems almost accidental, the scorpion may even withdraw for a time, but it waits patiently and finally achieves its aim. Then, especially if the victim struggles, it inserts its sting where best it can, often without any delay."

Hadley and Williams (1968) made observations on *Vaejovis confusus* Stahnke, *Paruroctonus mesaensis* Stahnke, *Paruroctonus baergi* (Williams and Hadley), *Hadrurus arizonensis pallidus* Williams, and *Centruroides exilicauda* (Wood). They found that "scorpions generally used their venom apparatus at the time of prey capture." They note that several species of mice and lizards preyed upon by *H. a. pallidus* appeared immune to the venom, however. Although the scorpions observed by Hadley and Willliams usually grasped the prey in the pedipalps before employing the sting, this was not always so. If the prey fought back aggressively, the scorpion sometimes stilted on its walking legs with the mesosoma and metasoma arched in almost a vertical position, from which posture the scorpion could strut slowly or twirl around in small circles, stinging blindly at its target.

Bub and Bowerman (1979) studied prey capture in *Hadrurus arizonensis* Ewing and found that the prey was stung at least once in all sequences observed. Baerg (1961) points out that scorpions with large pedipalps and reduced metasomas probably do not use the sting to immobilize their prey. Burton (1975) writes that scorpions will only use the sting if the prey offers resistance. Cloudsley-Thompson (1951) notes that *Euscorpius italicus* (Herbst) seldom, if ever, uses the sting to subdue prey. On the other hand, *Scorpio maurus* Linnaeus, *Buthus occitanus* (Amoreaux), and *Androctonus australis* (Linnaeus) will lash out with their sting at the slightest provocation (Cloudsley-Thompson 1958).

In sum, accounts in the literature tend to state generally that the sting is only used in prey subdual if the prey struggles excessively. However, when species are individually examined some tend never to use their sting and others always use their sting. There appears to be an inverse relationship between the size of the pedipalps and the frequency of stinging behavior. Those species with large powerful pedipalps appear to rarely use their sting (for example *P. imperator, H. longimanus,* and *A. phaiodactylus*), while those species with small slender pedipalps use the sting frequently (*H. arizonensis, U. manicatus, B. occitanus, Vaejovis* spp.).

STING USE IN *P. IMPERATOR*

Pandinus imperator is a species with large powerful pedipalps. The metasoma is also well developed. Although the sample size was too small for statistical analysis, the present observations indicate that *P. imperator* seldom, if ever, uses the sting in prey subdual as an adult. In this respect *P. imperator* is similar to

E. italicus and *H. longimanus* (Cloudsley-Thompson 1951, Schultze 1927). *Heterometrus longimanus* is also a large species with well developed pedipalps. (Information on the morphology of *E. italicus* was not available.)

An ontogenetic change in prey capture behavior was evident in the present study. The young *P. imperator* used their stings on crickets frequently as they grew. At 6-8 cm in length these scorpions changed their prey capture behavior and dispatched crickets with the pedipalps or devoured them alive. These scorpions were then entered into the feeding trials with mice, where they reverted to their earlier stinging behavior to subdue mice larger than 4 cm in length but continued to dispatch smaller mice via pedipalpal action alone or by devouring them alive.

Why use of the sting in prey capture should be phased out as *P. imperator* matures is an interesting question. Possibly the use of the sting increases the prey capture success of the young scorpions, thereby imparting a survival advantage. No information on the natural prey items of *P. imperator* was available, but it is likely that by using the sting the young scorpions make available a greater variety of prey, obtain prey more efficiently, and consequently grow rapidly during a period of life when mortality is undoubtedly high. But if use of the sting is advantageous in capturing prey, why is its use lost in the adults? Possibly, once the scorpion has attained a certain size its pedipalps alone are large enough and powerful enough to dispatch any normal prey item, and prey items large enough to necessitate stinging are rejected in favor of smaller items which pose less of a risk of injury to the scorpion. Also, venom production may be costly from an energetics standpoint. Whether or not this is so, it was clear in the present experiments that the use of the sting would have saved much energy in struggling with the prey item. In fact, if not for the confines of the terraria it is unlikely that the scorpion could have caught the mouse in the first place, much less be able to make a second attempt after the mouse escaped an initial grasp. Clearly, further investigations will be necessary to explain the biological significance of this ontogenetic behavioral change.

CONCLUSION

An ontogenetic change in prey capture behavior, involving loss of stinging behavior in prey subdual, was observed in two captive born *P. imperator*. At 6-8 cm in length these scorpions abandoned sting use in prey subdual, but at 10 cm in length were shown to revert to the juvenile stinging behavior if confronted with prey too formidable to be subdued via pedipalpal action alone. Wild caught adult scorpions at least 14 cm in length refused to utilize the sting in prey subdual, apparently rejecting prey too large to subdue with the pedipalps alone. The ontogenetic change in prey capture behavior demonstrated in *P. imperator* may occur in other scorpions as well, and needs to be investigated especially in those species noted for infrequent or absent stinging behavior (*H. longimanus, E. italicus, A. phaiodactylus*). The biological significance of this ontogenetic change is at present unknown.

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